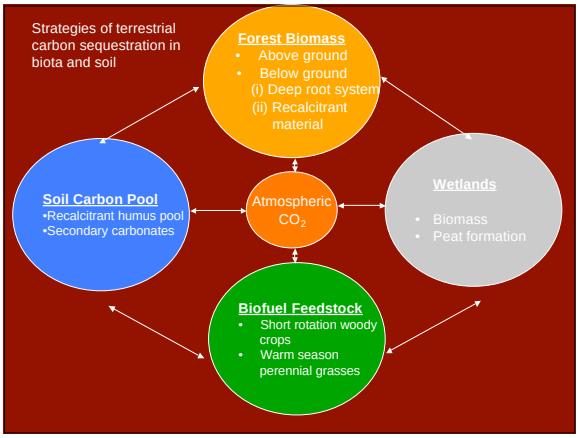
# Carbon Sequestration in Terrestrial Ecosystems

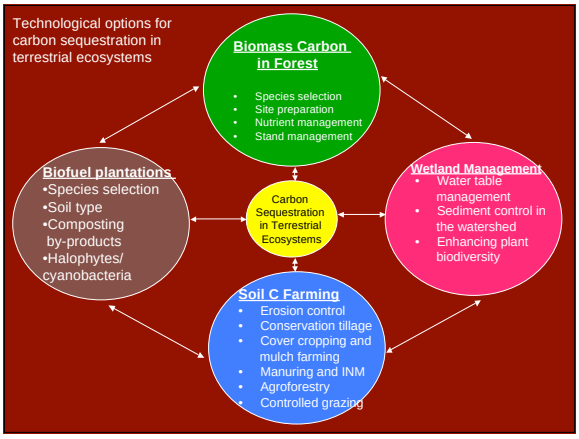
## MRCSP-Phase II

## Partners

1. OSU : R. Lal, H. Blanco, U. Mishra
2. WVU: M. Sperow, L. McDonald
3. UM : B. Needleman, M. Rabenhorst, R. Weil, R. Crew



Technological options for carbon sequestration in terrestrial ecosystems




# Importance of Soil Organic Carbon

1. Improves soil structure and tilth
2. Reduces soil erosion
3. Increases plant available water
4. Stores plant nutrients
5. Provides energy for soil fauna
6. Purifies water
7. Denatures pollutants
8. Increases biodiversity
9. Improves crop/biomass yields
10. Moderates climate

**It makes soil a living ecosystem**
**It is a nations most precious natural resource**

# Soil C Dynamics

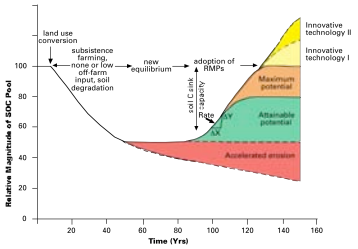



Fig. 3 A schematic of the soil C dynamics upon conversion from a natural to agricultural ecosystem, and subsequent adoption of recommended management practices (RMPs). In most cases, the maximum potential equals the magnitude of historic C loss. Only in some soil-specific situations, the adoption of RMPs can increase SOC pool above that of the natural system. An example of this is acid savanna soils of South America (Llanos, Cerrados) where alleviation of soil-related constraints can drastically enhance the SOC pool.

## Soil Carbon Sink Capacity

| Region | Capacity (million t/yr) |
|---|---|
| Ohio | 10 |
| USA | 300 |
| World | 1000 |

## Carbon Sequestration in Agricultural Soils OSU Objectives

I. Quantify the rate of soil organic carbon (SOC) sequestration in croplands, minesoils, and wetlands.

II. Measure SOC pool under different land use and management systems for the whole MRCSP region.

III. Predict and map SOC on a regional scale using pedometric tools.

IV. Relate SOC stock to soil physical quality.

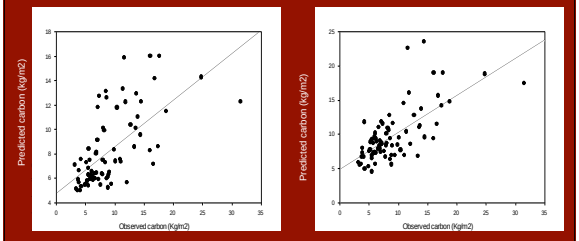
## Data Sources

- Georeferenced SOC profile data from NRCS data base.
- Digital Elevation Model from USGS data base.
- Temperature and precipitation data (30 yrs) from NCDC data base.
- Land use data from USGS data base.

## Results

- SOC is mainly stored in the topsoil, but in some soils more SOC is stored in subsoil.
- Areas with high subsoil SOC stock are located in regions with nearly flat soils positions (< 5%) indicating poor drainage conditions.

## Results



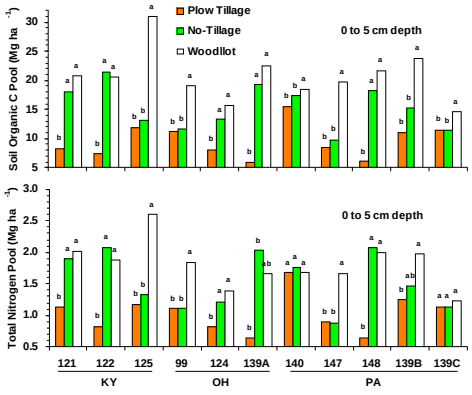

Observed and predicted SOC stock from 0 to 1 m soil depth.

## CHARACTERIZATION OF SOIL-PROFILE SOC SEQUESTRATION AND STRUCTURAL PROPERTIES

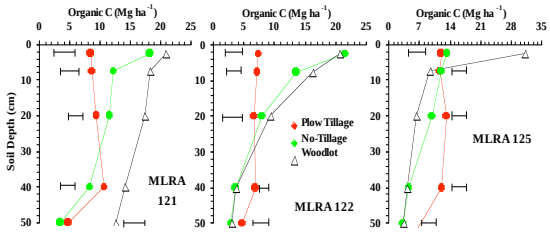
- Data on measured SOC stocks on a regional scale are limited.
- Data on soil parameters to predict SOC stocks under different land use and management systems are needed.
- Impacts of SOC pool on soil physical quality are not well understood.

## FIELD WORK


## Soil Organic Carbon and Nitrogen Pools

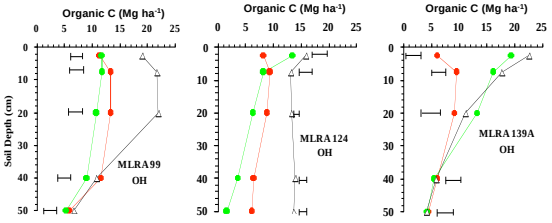



## SOIL-PROFILE C STORAGE IN KENTUCKY THREE MLRAs



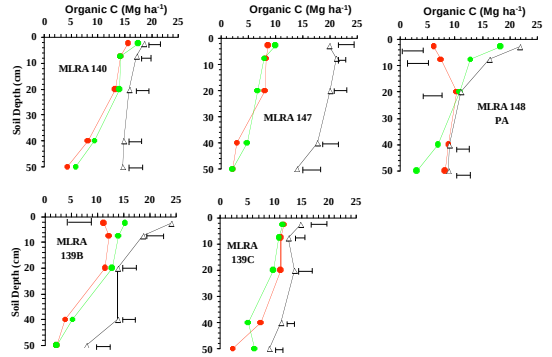

No-till farming generally stores more SOC than plowed soils in the topsoil.

## SOIL-PROFILE C STORAGE IN OHIO
## THREE MLRAs

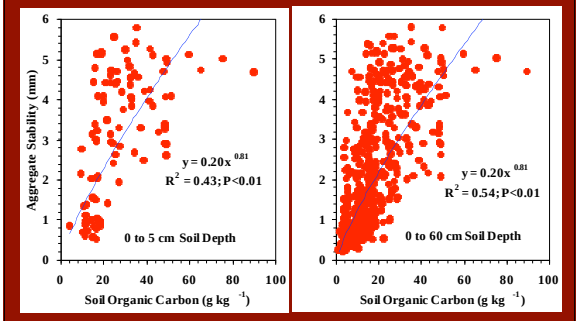



**No-till farming generally stores more SOC than plowed soils in the topsoil.**

## SOIL-PROFILE C STORAGE IN PA, SIX MLRAs




## ORGANIC CARBON STABILIZES SOIL AGGREGATES



## FUTURE WORK

- **Further expansion of measured SOC database for the MRCSP region.**
- **Mapping estimates of SOC using pedometric tools.**
- **Estimation of SOC using readily available soil properties.**
- **Development of regression models to estimate on-farm SOC pool needed for C trading in the CCX.**

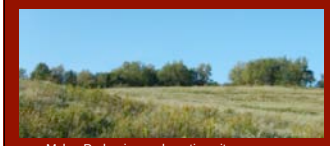
## Minesoil – WVU Overview

- **Primary objective**: Estimate the amount of soil carbon that may be stored in mine sites reclaimed to grass and/or legumes.
- Soil samples from multiple mine sites where mining activities ended at different times collected
  - Assess change in soil carbon over time.
  - A mine site where reclamation activities just began is being used to assess the soil carbon content at the beginning of reclamation activities.
  - This information, combined with soil samples collected from the same site over time, enhances estimates of the amount of soil carbon storage.
- **Secondary objective**: Estimate the economic consequences of activities adopted to enhance carbon sequestration on all MRCSP region land uses.

## Reclaimed Mine Site Descriptions

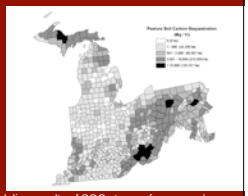
| Site Name | Mylan Park | Skousen | Dent's Run | New Hill |
|---|---|---|---|---|
| Owner Name | Mon County School Board | Dr. J. Skousen | | Patriot |
| Pre-Mine Land use | Forest | Forest/pasture | Forest | Ag, pasture, and forest |
| Mining Began | 1982 | 1996 | 1999 (June) | 2003 (Spring) |
| Mining Ended | 1990 | 1998 (January) | 2000 (October) | 2005(Fall) |
| Coal Seam | Waynesburg | Waynesburg | Waynesburg | Waynesburg |
| Mining Method | Contour Mining, Front end loaders | Contour Mining, Front end loaders | Contour Mining, Front end loaders | Contour Mining, Front end loaders |
| Type of Overburden | 70-80% Sandstone, rest is shale | ~80% Sandstone, rest is shale | 70-80% Sandstone, rest is shale | 70-80% Sandstone, rest is shale |
| Reclamation Method | Backfilled, 3" topsoil, grass and legumes | Backfilled, 8" topsoil, grass and legumes | Backfilled, 3" topsoil, grass and legumes | Backfilled, 3" topsoil, grass and legumes |

## Grass/Pasture Mine Reclamation in MRCSP Region



Mylan Park mine reclamation site.

- Historic predominant post-mining land use is grass/pasture.



Modeling results of SOC storage from grass/ pasture on Reclaimed mine sites in MRCSP region.

## Soil Sampling at Reclaimed Mine Sites

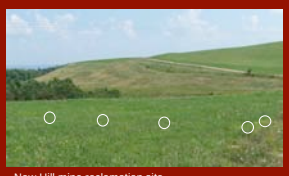
- Number of samples collected from each site:
  - Samples were collected along a diagonal transect for each terrain from two different depths: 0-6 cm and 6-12 cm.
  - Due to shallow soils, the sampling to the deeper depths limited
  - Total of 524 soil samples collected (358 in 2006 and 166 so far in 2007)
- Summary of soil sampling

Graduate student (Sri) marking sampling locations at the New Hill site.

| Year | Depth | Dent's Run | Mylan Park | New Hill | Skousen |
|---|---|---|---|---|---|
| 2006 | 0 – 6 cm | 53 | 54 | 52 | 30 |
| | 6 – 12 cm | 39 | 60 | 44 | 26 |
| 2007 | 0 – 6 cm | Soon | 65 | 54 | Soon |
| | 6 – 12 cm | Soon | 11 | 36 | Soon |
| Total | | 92 | 190 | 186 | 56 |

## Preliminary[1] Results from New Hill Site

| | 2006 | | 2007 | |
|---|---|---|---|---|
| | **0-6 cm** | **6-12 cm** | **0-6 cm** | **6-12 cm** |
| Mean SOC (Mg C $ha^{-1}$) | 9.4 | 9.7 | 11.2 | 7.6 |
| Range (Mg C $ha^{-1}$) | 3.6 - 21.4 | 5.0 - 24.9 | 2.3 - 19.0 | 4.1 - 21.0 |

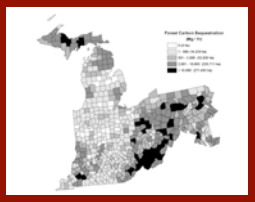


New Hill mine reclamation site.
Orange flags (circled) identify sampling points.

| Change 2006 - 2007 | Mean SOC (Mg C $ha^{-1}yr^{-1}$) |
|---|---|
| **0-6 cm** | 1.9 |
| **6-12 cm** | -2.1 |

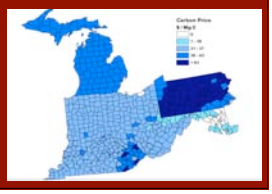
[1] Results should be viewed with caution – 2007 data are incomplete.

## Analysis of Carbon Storage in Forests on Reclaimed Mineland



- Forestry as reclamation activity offers opportunity for increased carbon storage
  - Soil carbon
  - Litter layer
  - Above-ground biomass

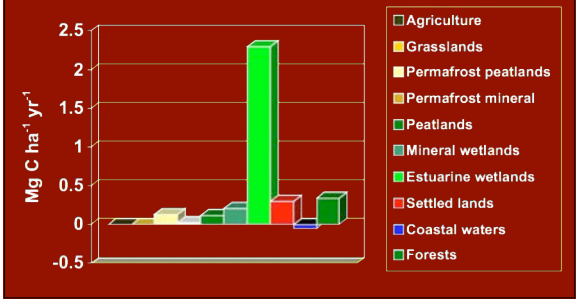
- Value of carbon stored on reclaimed mine land planted to forest estimated
- Based on difference between reclamation costs to grass and forest
  - Final grading
  - Fertilizer
  - Tree planting



## UM-Tidal marshes: Maximizing terrestrial carbon sequestration

- High net primary productivity and low decomposition rates
- Minimal methane production (salinity dependent)
- As sea-level rise increases, so does sequestration potential
- Accretion = Long-term continual C sequestration
- The State of the Carbon Cycle Report (SOCCR)
  - Estuarine wetlands highest ecosystem for carbon sequestration and generally have minimal methane production

## Current carbon mean flux density in North American ecosystems (SOCCR report draft 3/07)



## Research Design

- Two tidal marsh cells
  - One newly created 2.7-acre cell (2003)
  - One natural marsh cell
  - 2008: adding newly restored cell pending restoration

## Research Methods

- ~15 field plots per SET (~45 per cell)
  - Feldspar marker to track vertical accretion
- Plots sampled annually for soils and vegetation
  - Organic carbon, organic matter, mineral content
  - Bulk density
  - Porewater: Nutrients, sulfides, salinity
  - pH
  - Particle-size
  - Vegetation: cover, aboveground biomass, species
- Instrumentation at each cell
  - Water table
  - Redox potential
  - Methane emissions

## Update

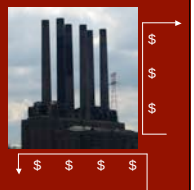
- 2007 sampling completed
- 2007 sample processing and analysis ongoing
- Initiated methane emissions monitoring in collaboration with Dr. Patrick Megonigal at the Smithsonian Environmental Research Center
- Media: Front page story in Baltimore Sun 10/9/07 entitled “Can this muck save the planet?”

## Kicking the Carbon Habit

- Agriculture is an important part of the solution to rehabilitating the C-civilization
- It is a truly win-win-win strategy

## The Cost of Going Green






Step 1: Add total greenhouse-gas emission, compute $CO_2$ equivalent, then divide by annual revenue in millions of dollars. Result: total carbon intensity, or the amount of emissions per $1 million in revenue.

Step 2: Multiply total emissions by the current price of carbon offsets-$32 per metric ton on the European market. This yields the carbon footprint in terms of the total cost of offsetting emissions.

Step 3: Determine the price of reducing carbon as a percentage of the company's revenue. If the cost is too high, the business may face risks should carbon-cap legislation be passed.

…..Modified from (Walsh, 2007)